Energy Efficient High Performance Computing

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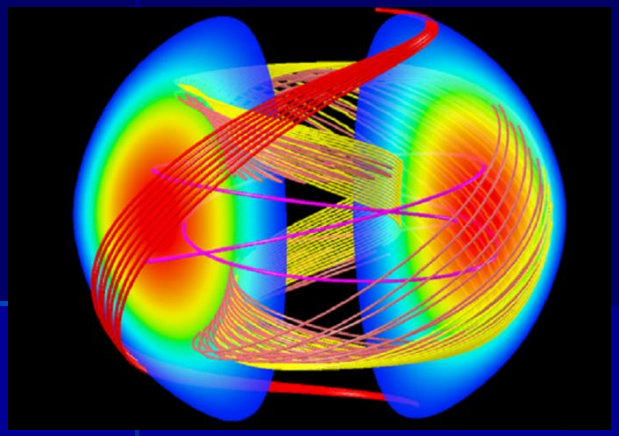
UC Berkeley's Computational Research and Theory (CRT) Facility

- **A new high performance supercomputer center for scientific computing in Berkeley, California**
- **High Performance Computing (HPC) center on first floor**
  - 32,000 square feet computer room
  - 7.5 MW initial total power requirement, expanding to 17 MW
- **Offices on second and third floors**
- **Mechanical space below HPC, chiller plant adjacent**
- **Total gross square feet 126,000**


Computational Research & Theory
University of California

CRT Facility

CRT Facility rendering



Site: 12 MW; 77 GWh; 2,132k GSf

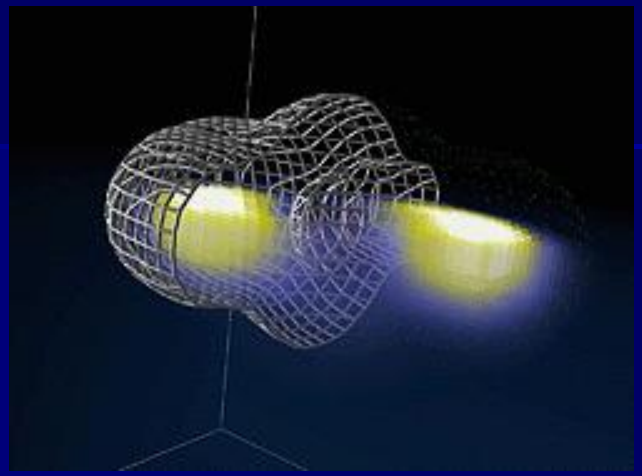
CRT building: 17 MW; 150 GWh; 32k computer room

Effect of CRT to overall campus:

peak power x 2.4

annual electricity x 2.9

CRT Project objectives



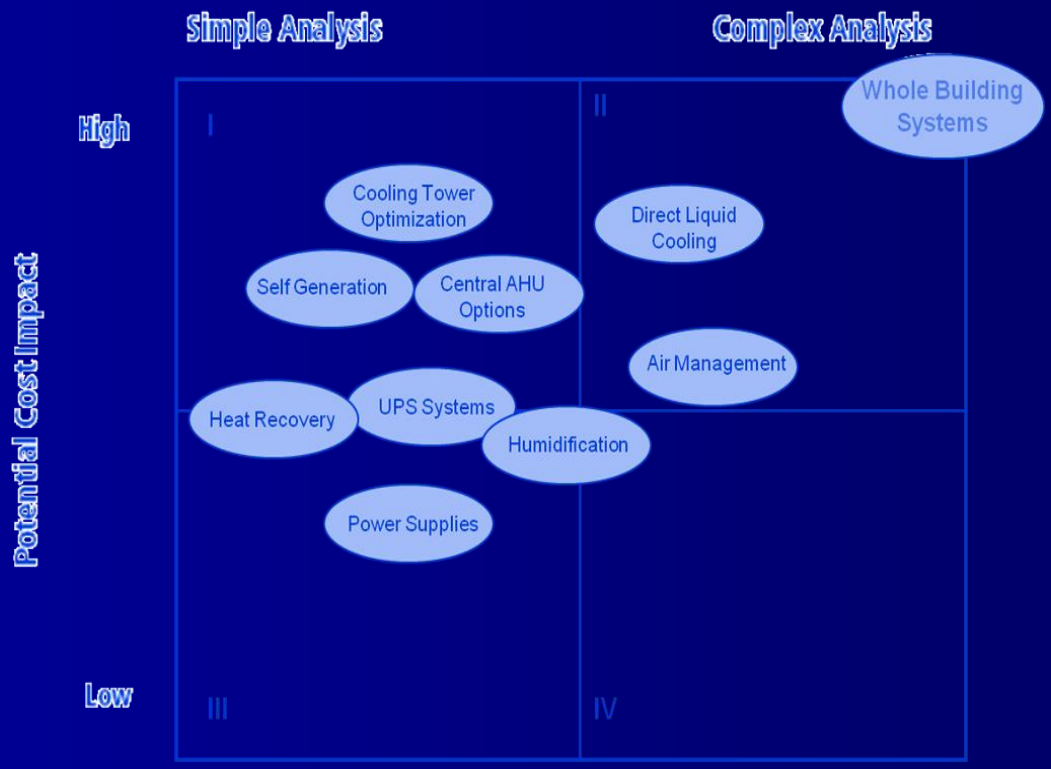
Major Project Objectives

- Leading HPC capability
- Model of energy efficiency
- Maximum flexibility for future systems
  - Computer systems layout
  - Air and/or liquid cooling
  - Front to back or bottom to top airflow
- Energy efficient infrastructure
  - PUE 1.2 or better based on annual energy
  - Efficient system design
  - Possible use of waste heat

Design advantages for Efficiency

- Mild climate suitable for “free” cooling
- Ability to use ASHRAE TC 9.9 recommended temperature range and expanded humidity range
- Use of air and/or water economizers
- Integrated design – building and mechanical systems
- Minimal UPS
- Adjacent use for waste heat

Many facets of efficiency



Flexibility for air or liquid cooling

- **Future Systems could:**
  - **Continue to be air cooled**
  - **Have liquid cooled cabinets removing some or all of the heat**
  - **Have liquid cooling to the processors**
  - **Use combination of refrigerant and liquid**
  - **Others?**
- **Network or storage equipment may continue air cooling even if servers require liquid**

Large efficient air handlers

Applying sound HVAC engineering for air movement:

- **Efficient fans and motors**
- **Low system pressure drop/ face velocity**
- **Variable speed**
- **Modular layout**
- **Effective air management**

Design Pressure Drops Across Major HVAC Components	
Components	**Initial Pressure Drop (in. w.g.)**
Outside Air Louvers	0.15
Outside Air Dampers	0.20
Filters	0.35
Direct Evap. Media Pad	0.25
Chilled Water Coil	0.25
Ductwork+Plenum+Outlets	0.30
Total	**1.5**

Modular design

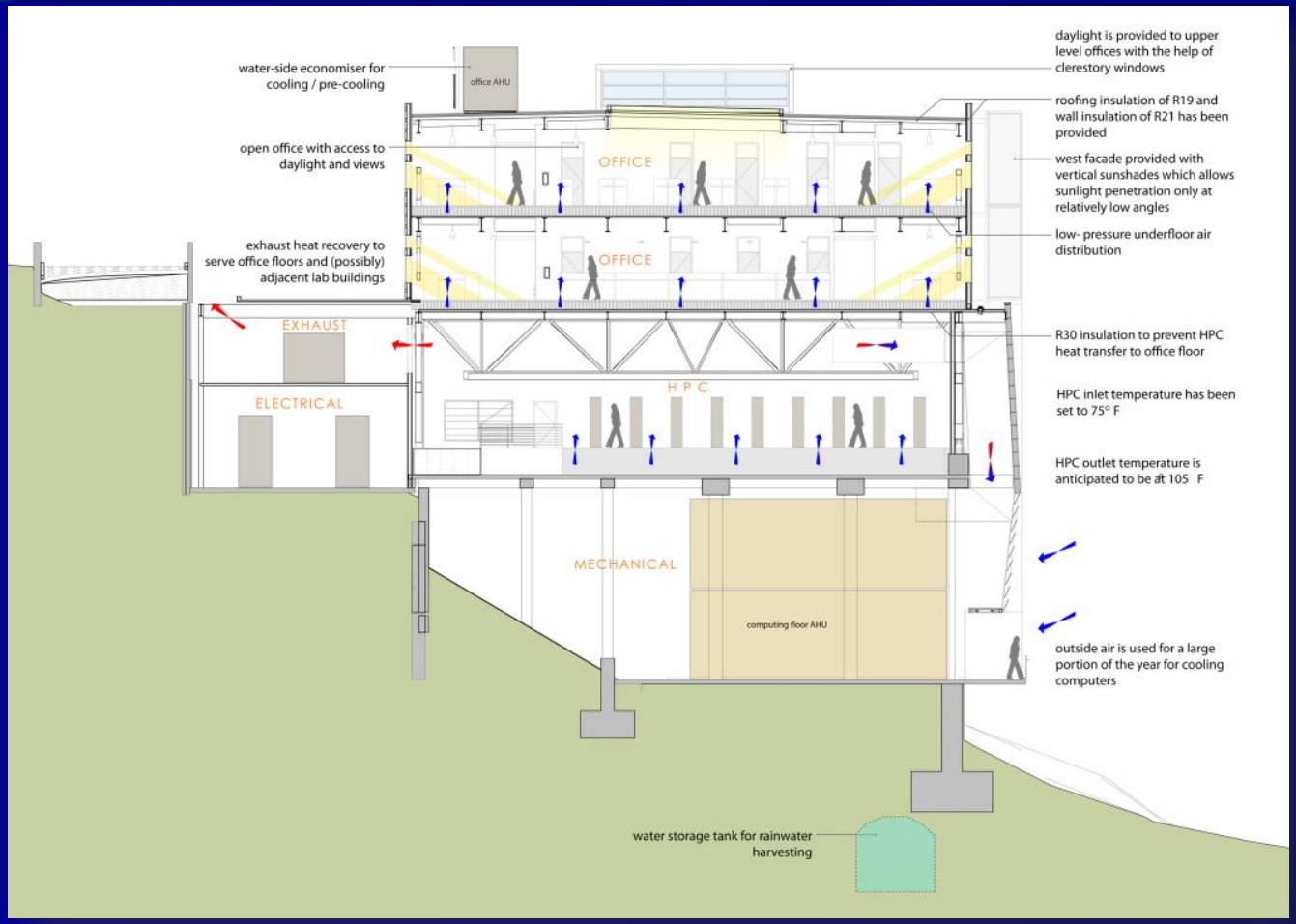
Building and system modular build out

- Add as you go
- Build only what you need
- Space to add systems later
- Typically 4 or more systems

Modular cooling plant

- Large headers sized for efficient operation for future loads -even higher efficiency in the interim
- All pumps, fans, and compressors are variable speed
- Chillers bid as an option and may not be installed
- Optimal control for maximum overall plant COP at any load and outdoor condition
- Space for additional chillers and cooling towers for future loads
- Headers, valves and caps for modularity and future flexibility allow additions without shutting down

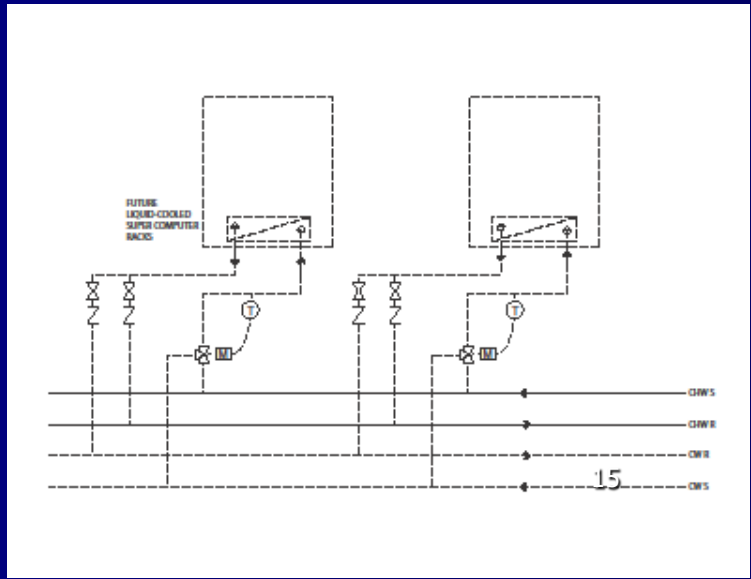
Cross section



Liquid cooling capability

Use of chilled water or treated water connected to cooling tower through heat exchanger for free cooling

- 4 pipe system allows all of one or the other - or mixing
- Blanked off for future addition
- Space for piping provided
- Reset for efficient operation



Part load operation

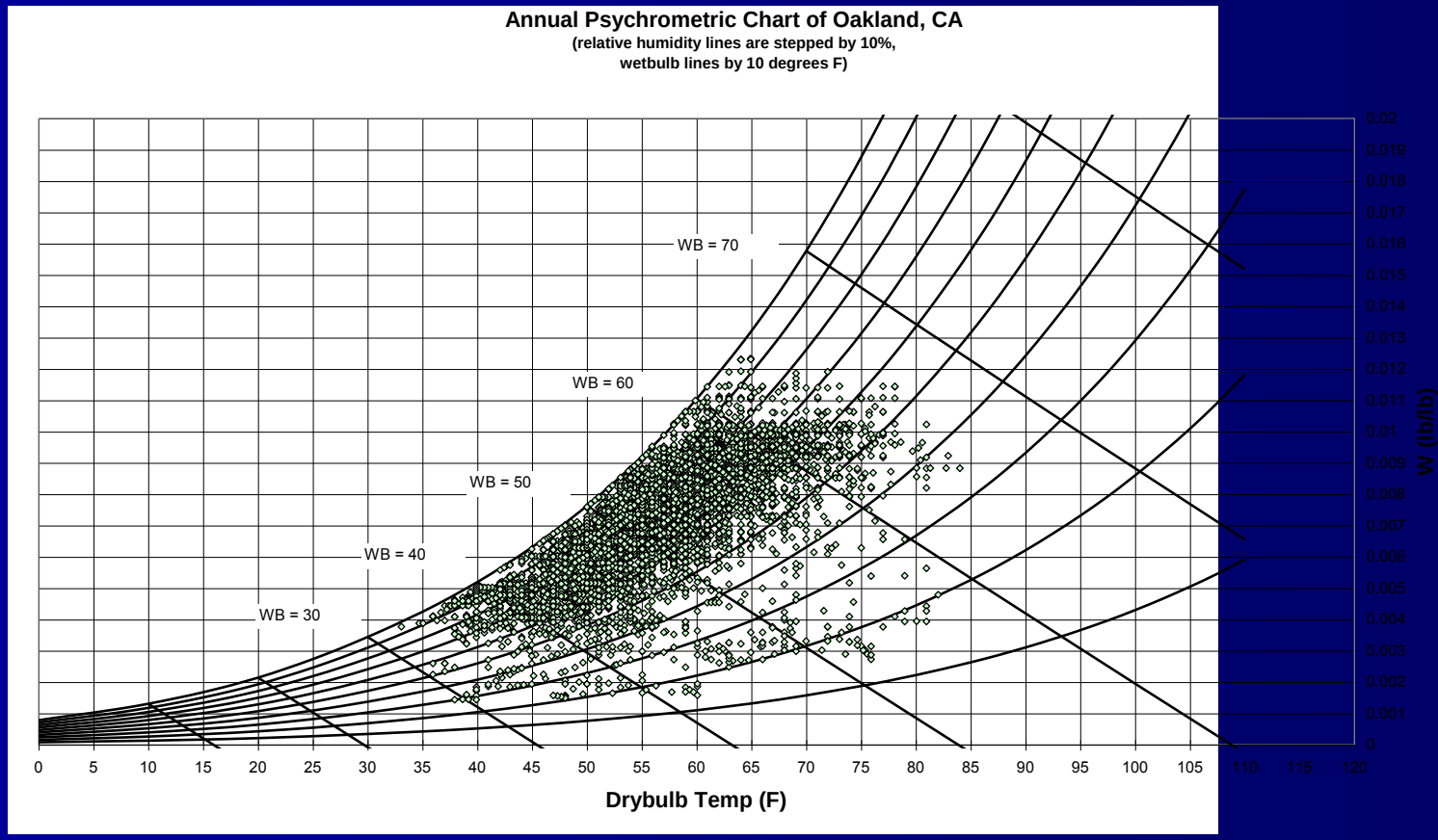
HPC systems operate at near full utilization however systems will be added and removed over the life of the facility varying the cooling requirements significantly

- **Modular**
- **Variable speed everything**
  - **tower fans**
  - **chilled water pumps**
  - **condensing water pumps**
  - **chiller**
  - **exhaust fans**
  - **main air handler fans**
- **Controls**

Environmental conditions

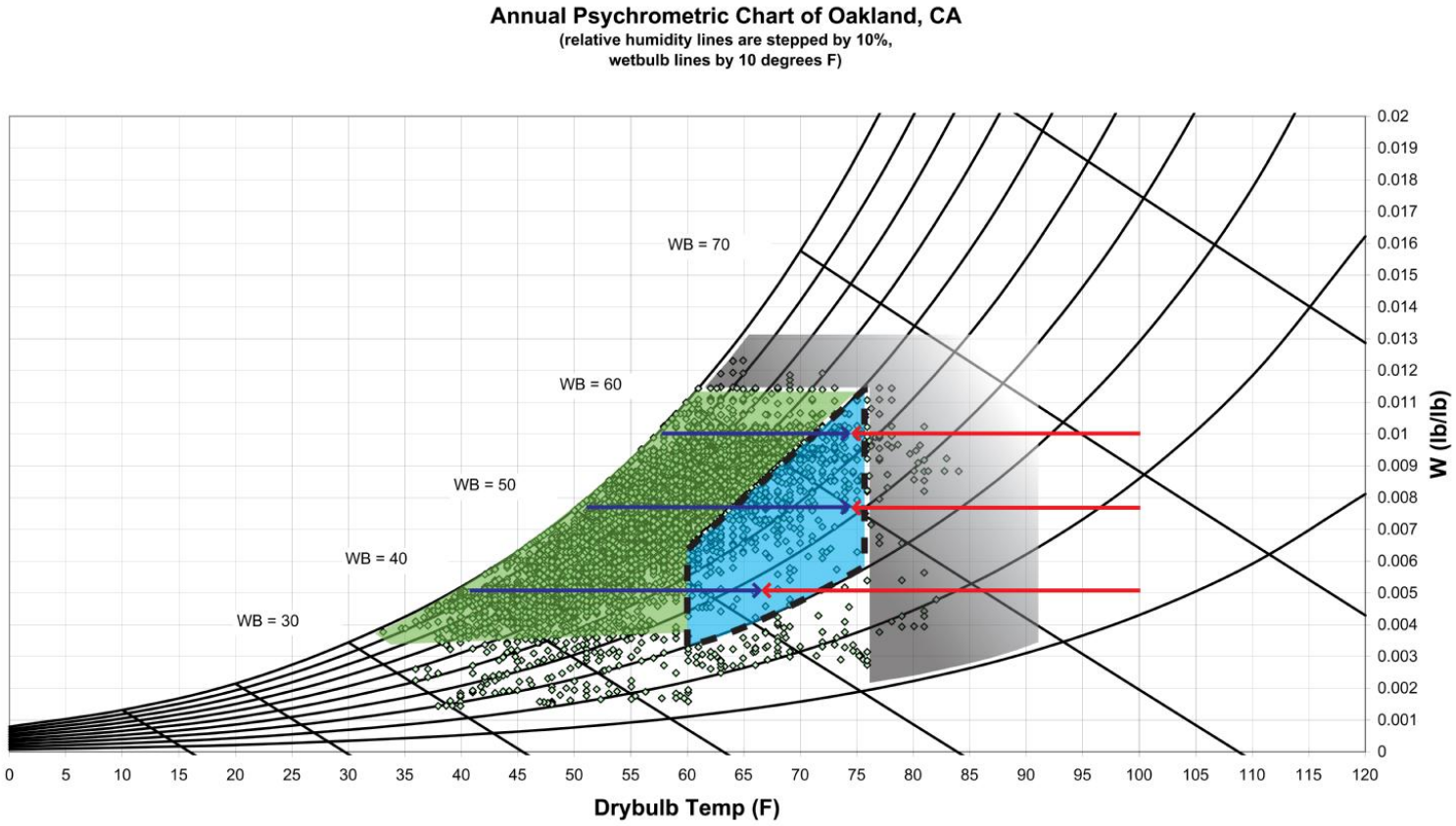
Design Conditions:

- Summer 100F DB/ 65 MWB; Winter 37.5F (99.5% Oakland ASHRAE)



Environmental conditions

CRT design guidelines: 60 to 75F DB; 30-60% RH



Environmental conditions – operating modes for air cooling

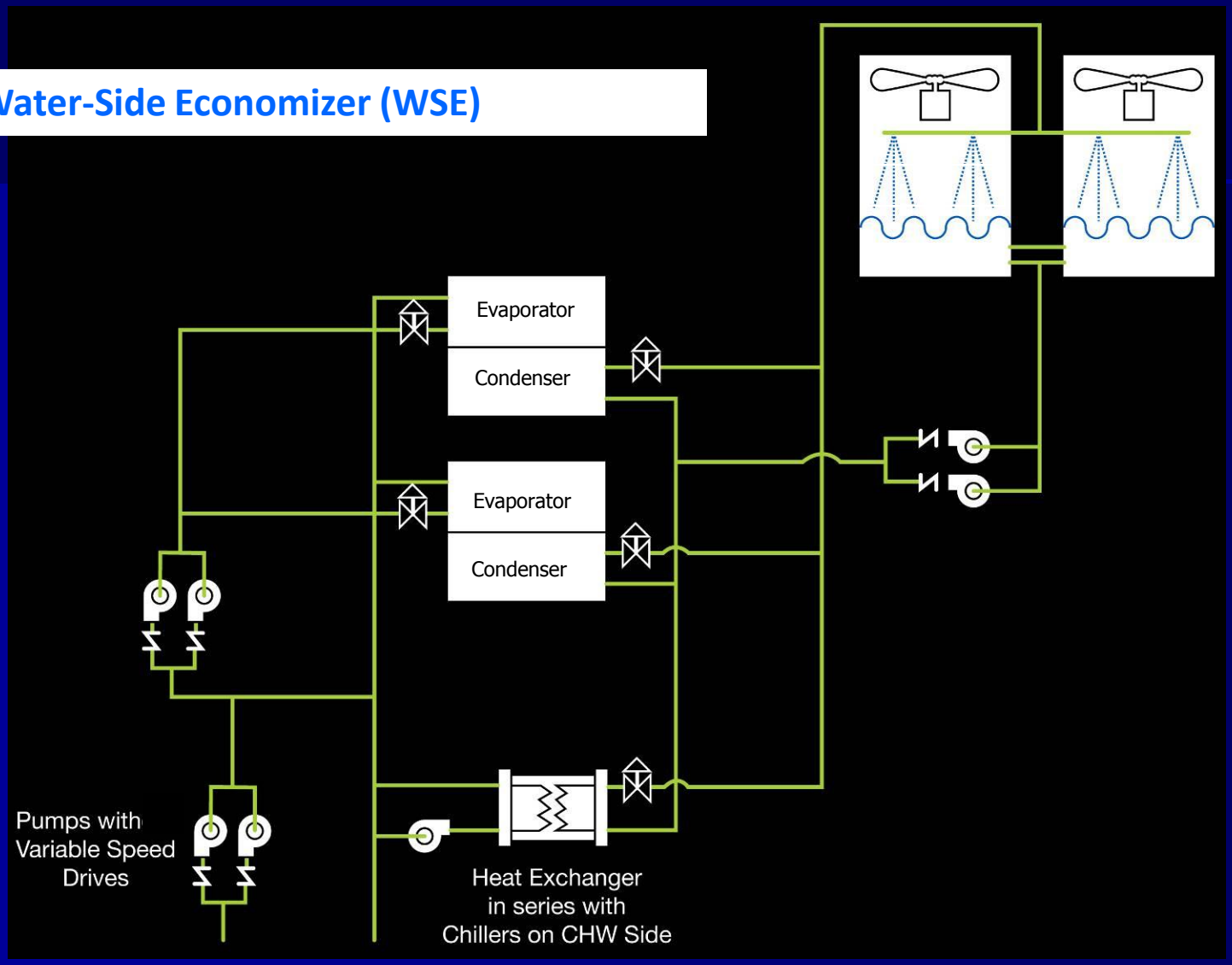
Operating Mode	Number of Hours Per Year	Percent of Year
Mix of outside and return air	8200 hours	93%
Direct evaporative cooling	45	0.5 %
Direct evaporative cooling and chilled water coil	38	0.4%
Chilled water coil	510	6%

Air economizer and evaporative cooling

- **Direct evaporative cooler doubles as humidifier**
- **Humidity allowed to float within recommended range**
- **Evaporative cooler has more pressure drop but lower life cycle cost relative to spray nozzles or ultrasonic humidifier**

Water side economizer

Integrated Water-Side Economizer (WSE)



Predicted HPC Performance

- **PUE of 1.16 based on annual energy**

- **Heat recovery is on top of this**

ERF = Reuse Energy/Total Energy

= Total Infrastructure – Reuse/IT

Reuse Amount is yet to be determined

Electrical systems efficiency

- **Minimal** use of UPS
- Efficient UPS at operating conditions
- Premium efficiency motors
- Efficient transformers
- Lighting Controls

Commissioning

- **Commissioning agent (and Construction Manager) involved at design stage**
- **Commissioning plan developed early**
- **Plan to commission all systems**

Monitoring

- Integrated monitoring and control possibly using wireless sensors
- Wireless monitoring is in place at two other LBNL data centers
- Real time PUE monitoring capability
- Environmental monitoring – many points
- System and sub-system monitoring

Wrap up

- **UC's supercomputer center will demonstrate some advanced efficiency concepts while being a leading scientific computing center**
- **Budgets are always a challenge**
- **Project is facing legal challenges**
- **Stay tuned**

Questions?